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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM NO. 427.

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By H. Herrmann.

PART II.

For the sake of comparison, speeds and water resistance are uniformly reduced to a total weight of 1000 kg (2205 lb.). The following results** were obtained by a comparison*** of the F-boats (designed at Felixstowe) with the competing seaplane Phoenix "Cork" or "P.5" of the English Electric Company, Ltd.:****

Type Engine	"F.5" Rolls-Royce	"P.5" Mk. I & Mk. II Rolls-Royce	"P.5" Mk. III Napier-Lion
Weight, light	9,100 lb.	7,350 lb.	8,000 lb.
Weight, loaded	12,700 "	11,600 "	12,500 "
Useful load	3,600 "	4,250 "	4,500 "
Horsepower	720	720	900
Speed at 2,000 ft.	87.5 mi./hr.	103.6 mi./hr.	109.4 mi./hr.
Climb to 2,000 "	7 min.	4 min.	3 min.20 sec.
" " 6,500 "	30 "	15 "	14 min.
" " 10,000 "	-	30 "	25 "
Service ceiling	7,000 ft.	13,000 ft.	13,000 ft.

* From "Berichte und Abhandlungen der Wissenschaftlichen Gesellschaft für Luftfahrt," December, 1926, pp. 126-152.

** Taken from "Flight," March 13, 1924.

*** Baker, G. S. and Keary, E. M. - Experiments with Models of Seaplane Floats. British Advisory Committee for Aeronautics Reports and Memoranda No. 483, December, 1918.

**** Hope, Linton - Flying Boat Hulls. "The Aeronautical Journal," August, 1920.

1. Owing to their large bottoms, the F-boats (Fig. 33) produced 12% lower resistance and less spray than the P-boats (Fig. 34), but leaped more easily.

2. The first step of the F-boat was then shifted 0.72 m (2.36 ft.) toward the front and the second step was shifted backward, thus increasing the water resistance by 12%, but improving the longitudinal stability on the water.

3. The height of the spray thrown up above the P.5 (Fig. 35) was reduced by 0.6 m (1.97 ft.) by shifting the rear step backward, but the stern post dipped into the water.

4. Sharpening the edge of the step in the P-boat (Fig. 35) for reducing the impact, resulted in an increase of resistance and spray, owing to the reduction of the effective portion of the bottom.

5. Lowering the step toward the inner part of the V-bottom, as shown in Fig. 36, produced a deficient separation of the water and an exceedingly high water resistance.

6. In all cases, leaping could be avoided by small nose-heavy or tail-heavy moments.

Investigations were also made for the purpose of replacing the transverse step by one or several longitudinal steps* (Fig. 38). However, this solution can never be seriously considered, even if it were hydrodynamically free from objection, owing to the difficulties and expense involved in its practical realization. The resistance is already too high and decreases too little beyond the critical speed (Fig. 39). The small planing angle and the high water moments, which cannot be controlled by standard horizontal tail planes, are in this case decisive.

The shape of the P.5 is subject to numerous changes.** Two different ways of increasing its width were tested (Fig. 40). The result is rather surprising owing to the slight influence exerted by different loads on hulls of the same size. Every increase of width results in an increased resistance. Measurements with different angles of the forward portion are of greater value (Fig. 42). According to Fig. 44, the load imposed on a hull can be augmented without increasing the formation of spray, by raising the bow and extending the overhang. However, the water resistance increases when the bow is raised. These conditions, as shown by Fig. 44, in which the resistances refer to a total weight of 1000 kg (2205 lb.), signify that, for a higher raised

*Baker, G. S. and Keary, E. M. - Experiments with Model Flying Boat Hulls. Comparison of Longitudinal with Transverse Steps. Aeronautical Research Committee R&M No. 893, August, 1923.

**Baker, G. S. and Keary, E. M. - Experiments with Model Flying Boat Hulls and Seaplane Floats. Possibility of Loading a Flying Boat, the Beam and the Angle Forebody being Varied. British Advisory Committee for Aeronautics R&M No. 655, Jan., 1920.

bow, the size of the hull can be reduced, the formation of spray remaining unchanged and the additional resistance being slightly lower.

Based on these tests two new bow shapes were investigated (Fig. 43). Their water resistance is also shown in Fig. 44. The distribution of water resistance was determined by dividing the model at the step and measuring the resistance of the front and rear parts separately (Fig. 45). The resistance of the rear part was negligible. The effect of reducing the width of the hull* was also considered (Fig. 50). The result (Figs. 51-53) was most flattering for Linton Hope, the pioneer designer of shapes, who, owing to his experience in the motor boat line, had anticipated that either reducing or increasing the width of the hull would result in an increase of the resistance.

Very low water resistances were obtained during tests with three hulls of high displacement at normal take-off speed** owing to the fact that the take-off speed was low when compared with the size of the hulls. This fact is clearly shown by Fig. 49, all the data being reduced to a displacement of 1000 kg (2205 lb.). Compare length of hull, critical speed and water resistance with those in Fig. 44.

*Baker, G. S. and Keary, E. M. - Experiments with Models of Seaplane Floats. British Advisory Committee for Aeronautics R&M No. 300, November, 1916.

**Keary, E. M. - Experiments with Models of Flying Boat Hulls and Seaplane Floats. Comparison of the Vigilant Straight Frame Type and Curved Section Flying Boats. Aeronautical Research Committee R&M No. 785, January, 1922.

The air resistance of twin-floats does not considerably exceed that of an older normal landing-gear type. In this connection, measurements were made by Prandtl. Investigations on air resistance of hulls with open cockpits and ring mounts were made by the English.

It is wrong to believe that the P.5 without step has a higher resistance. The climbing speed was 24 m/s (78.7 ft./sec.). The measurements are not very accurate and chiefly made for comparison. According to Prandtl, an entirely smooth streamline body has a coefficient of drag C_w of approximately 0.05, which is less than half its normal value. In general, twin-float seaplanes or small flying boats are aerodynamically inferior to airplanes, if their characteristics are similar. On the other hand, a twin-engined flying boat is, in most cases, aerodynamically superior to a twin-engined airplane of the same size.

Air Resistances of Flying-Boat Hulls.

Type	Figure	$C_w = \frac{W}{Fq}$
P.5	34	0.1170
P.5 without steps	34	0.1438
N.4 Titania	29	0.1048
N.4 Atalanta	31	0.1074
F.3	33	0.1290

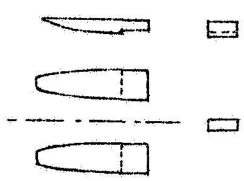
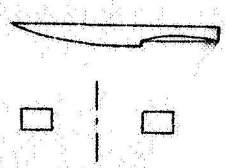
Different Constructional Shapes

In literature, normal designs are given less consideration than abnormal types. In practice, figures available for such seaplanes are usually wrong. Designers of abnormal seaplanes should always bear in mind that there is no use looking for new shapes, unless they procure considerable advantage or permit avoiding expensive patents. In any other case shapes and structural parts, which have proved satisfactory, should be retained. Twin-float seaplanes of 0.5 to 10 metric tons (1100 to 22000 lb.) total weight, and flying boats of 0.5 to 16 tons (1100 to 35270 lb.) have been built. Apart from seaworthiness, the hull or float problem is a question depending entirely on the purpose for which the seaplane is designed. If seaworthiness is not required, the twin-float seaplane is superior to the flying boat for total weights below 2 or 3 tons (4409 to 6610 lb.). Above this limit the problem has been solved in favor of the flying boat. For small seaplanes the advantage may lie on either side and sometimes both solutions are of equal value.

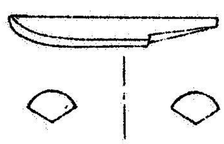
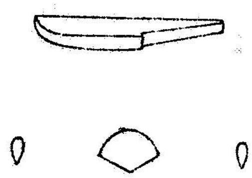
A) Twin-Float Seaplanes

A twin-float seaplane is not much else than an airplane adapted to marine purposes. Owing to the high transverse moments of the long front floats these seaplanes require larger vertical tail planes. To ensure good maneuverability on the water before the wind, the fin should be small and the rudder large. The propeller should be 0.5 m (1.64 ft.) above the surface of the water. The distance between the floats amounts to 1/5 of the span. No systematic investigations of stability on the water are as yet available. Work is at present entirely based on experimental data. The floats are divided into 5 to 7 water-tight compartments to avoid sinking, in case one of them should spring a leak. Thus far no investigations have been made on the stability of a leaky twin-float seaplane.

Comparison of Different Float Types

 Fig.54a	Short twin-floats with tail float used by the British Navy. Flat bottom (Fairey). Going out of use.	Step far aft. Seaplane raised during take-off by resulting nose-heavy water moment. When taking off on rough water, better maneuverability is ensured by means of the elevator control. Alighting at a larger angle than with long floats. Thus advantages for taking off and alighting on rough water. Long floating on rough water impossible, owing to high forces concentrated in the body (fuselage). Besides, large angle of attack results in premature take-off. Increased air resistance owing to bad shape. High water resistance due to bow wave. To be adopted when long flotation not necessary, but take-off and alighting on rough water essential.
 Fig.54b	Long twin-floats. Flat bottom German standard float. Going out of use.	Flat bottom. V-shaped aft to reduce impact on water. Can take off and alight in seaway 4 at 70 km/h (43.5 mi./hr.). Long flotation on rough water, if landing gear is strong enough. High impact on water. Well suited for wood construction. High water resistance due to bow wave.

Comparison of Different Float Types (Cont.)

 Fig.54c	Long twin-floats. V-bottom. Standard American type. Becoming more used.	30° V-bottom. Cut-away aft to obtain larger margin when pulling on elevator control. Appears to stand seaway 4 at 85 km/h (52.8 mi./hr.) owing to low impact on water. Long floating on rough water, provided landing gear sufficiently strong. Shape well suited for metal construction. Lighter than flat-bottom type. Low water resistance due to hollow lines.
 Fig.54d	Long central float with wing-tip floats. American training seaplane. Becoming more used.	V-bottom. Cut away aft to obtain larger margin when pulling on elevator control. Advantages when compared with twin-floats: lighter, lower air resistance, stronger, simpler and lighter landing gear. The compulsory wing-tip floats do away with the reduction of weight and air resistance. There only remains the advantage of a better landing gear. Maneuverability on rough water not so good as with twin-floats. Seaplane may break down if a wing-tip float comes off.

The above comparison shows the strong and weak points of different float constructions. It is interesting to note that the American marine float has a 32 to 35% lower resistance than the German standard float. The German float has a bow wave, whereas the American float runs in a hollow wave. Less spray is produced by models of the V-bottom type. Floats with a flat bottom run smoothly. V-bottom floats rock slightly. On the whole, floats with a V-bottom are much superior to floats without a V-bottom. The distance between the floats exerts a small negligible influence upon the resistance.

The landing gear should absorb the impact and the stresses between the floats during long floating on the water. Formerly the landing gear had a great number of struts. Nowadays it is subject to a thorough static calculation. The following forces must be taken into consideration:

1. The front impact at 1/3 bottom length from the bow.
2. The impact below the step.
3. The impact of the rear part.
4. The moment of torsion around the longitudinal axis.
5. The lateral impact drawing the floats asunder or pressing them together.
6. Combination of different forces as, for example, front impact on the right float and below the step of the left float, in addition to a moment of torsion around the longitudinal axis. This case occurs when alighting at an angle of 45° to the waves.

Under these conditions, the stresses may be higher than an impact on the right side of the front part and on the left side of the rear part in addition to a moment of torsion. Fig. 58 is a typical example of a landing gear which is not seaworthy, since the transverse forces and moments of torsion acting between the floats around the longitudinal axis are not sufficiently absorbed.

The following values are given by Lewe* for seaworthy seaplanes (seaway 4) at 80 km/h (49.7 mi./hr.) alighting speed and

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*Lewe, V. - Shape and Strength of Seaplane Under-Structures with Special Regard to Seaworthiness. "Zeitschrift für Flugtechnik und Motorluftschiffahrt," May 15, 1920. (Issued as N.A.C.A. Technical Memorandum No. 37.)

for floats without V-bottom:-

Front impact: six times the weight,

Rear impact: four times the weight,

Lateral impact: two times the weight of the floats.

The forces increase with the square of the alighting speed relative to the water. At seaway 4, a head-wind equal to half the take-off speed must be taken into consideration. Hence, when the minimum speed in the air is increased from 70 to 100 km/h (43.5 to 62 mi./hr.) the speed relative to the water changes from 35 to 65 km/h (21.7 to 40.4 mi./hr.). The squares grow from 4900/10000 = 2.04, to 1220/4250 = 13.5. Of course this calculation is confined to the impact of high waves when alighting on rough water.

Lower forces are created, if the landing gear is elastic, since, in this case, the impact does not fully develop. It is difficult to determine the proper degree of elasticity. Cables and wooden struts are the best means of achieving flexibility. Attempts were frequently made to provide floats with shock absorbers but these devices were never definitely adopted. This was probably due to defective arrangement. The weight of the floats should naturally be deducted in landing gear calculations.

B) Flying Boats

For a total weight of 3 to 5 metric tons (6614 to 11023 lb.), the flying boat is superior to the twin-float seaplane. The main reasons are:

1. General Considerations

Multi-engine principles are applied to seaplanes of such size and the twin-float seaplane is also equipped with lateral power units. The hull of a flying boat is more roomy than the fuselage of a corresponding airplane.

2. Seaworthiness

A flying boat of such size is seaworthy, provided the alighting speed is sufficiently low. Very high stresses are created between the floats of a large twin-float seaplane when floating on a rough sea.

3. Air Resistance

Except for the step, the shape of a flying boat is aerodynamically quite satisfactory. Consequently, a flying-boat hull including wing-tip floats, has less air resistance than a corresponding fuselage with floats and landing gear.

4. Water Resistance

Practically, hull and V-bottom floats are of the same value, but the hull is greatly superior to the German flat-bottom float. Large flying boats have often less resistance than large twin-float seaplanes.

5. Weight

A multi-engine, twin-float seaplane is much heavier than a corresponding flying boat.

6. Maneuverability

A flying boat of such size is more easily maneuverable on the water.

No wonder that the ambition of most designers tempted them to work their own way in the development of these large-sized seaplanes, the result being a great variety of types. Several types are reproduced in Fig. 68 for comparison. Nose-heaviness in gliding is a result of the propeller thrust acting above the resultant of the resistance. It can be reduced by good aerodynamical properties.

Longitudinal stability on the water results from the long bow which is also required for other reasons. The determination of the stability of leaky hulls can be based upon investigations on the stability of leaky ships. The lower wings should be 1.5 m (4.92 ft.) above the water and the cockpits at least 0.9 m (2.95 ft.).

Transverse stability calls for special measures unless the double-hull principle be adopted. The following measures must be considered:

1. Wing-tip floats above the water line. Most extensively used. Owing to negative metacentric height the flying boat at rest lies on one side. When taking off, it is straightened by water forces. The wing-tip float has a sharp V-bottom and bow to plow the waves more easily. Its top is highly cambered to ensure good flow-off of the water. The air resistance of

wing-tip floats is easily overestimated. The main trouble with them is that the seaplane breaks down if one of them comes off.

2. Wing-tip floats below the water line are used in some cases. They must be strongly V-shaped to avoid high impact on the water when alighting. These floats come off more easily than those lying above the water line. In this case, a breakdown of the seaplane is unavoidable. Air resistance and weight of the float exert a considerable influence. Turning with such floats on rough water is nearly impossible.

3. Chines, wing stubs and wings dipping in the water are seldom used, owing to difficulties resulting from patents. Very large chines, as used on English flying boats, may raise the metacentric height so far as to make wing-tip floats superfluous. However, it is more advisable to use wing-tip floats, owing to the high-water and air resistance and weight resulting from the necessary widening of the hull, which is particularly great for small flying boats.

The lower wing of biplanes may be designed to dip in the water. An example is shown in Fig. 69. Up to the present time only one experimental flying boat of this type has been built. It must be decided whether the advantage resulting from the absence of wing-tip floats is not counterbalanced by the increased weight of the lower wing and its attachment fittings, which must be very strong.

Wing stubs, as developed by Dornier, are obtained by cutting off the lower wing of such flying boats at a short distance from the center. To prevent these stubs from cutting the waves they should be set at a sufficiently large angle. This angle should be increased when the size of the flying boat is reduced. The part of the wing back of the rear spar is cut off to avoid a reduction of the lateral moment of inertia of the water line through overflowing of the suction side for any position of roll. Thereby the resistance of the section is not excessively increased. The induced drag and angle of wing setting are of course rather large. Wing stubs are not suitable for biplanes.

The use of metal in float and hull construction is steadily increasing. Wood gets easily soaked. With regard to durability, it must be chiefly taken into consideration that wood decays, steel rusts and light metals corrode. The practical difference between wood and metal construction is usually exaggerated. The advantage lies with the metal hull and float. Protection against atmospheric influences is equally important for all materials. Water is 800 times heavier than air. Air containing 1% of water produces an 8 times higher dynamic pressure. Attention is thus drawn to the superiority of strong metal covering and to the necessity of using resistant dopes for all parts.

In the course of development, all possible methods of construction were applied to the hull. Only homogeneous constructions lasted. Others such as wood and metal, steel-tube framework and duralumin or wood-and-wire hull with mahogany covering, although very expensive, were never satisfactory. Highly resistant hull or float parts should not be placed near considerably weaker parts. Deformations and deflections are continually produced when taking off, and when alighting or floating on rough water. The designer should clearly visualize the stresses engendered in all structural parts by elastic deformation, resulting automatically from impacts which, for wood and duralumin, are not small.

The best floats have probably been built in Germany. The English Linton Hope hulls, now built by The Supermarine Aviation Works, Ltd., are the best wood hulls. When dry, they are slightly lighter than the corresponding English metal hulls. Without doubt the weight of metal hulls, to be built in England after sufficient experience is gained, will not exceed that of wood hulls. However, the advantage resulting from lower weight becomes fully apparent when the wood hull gets soaked. Germany and America lead in the construction of metal floats and hulls.

Metal floats and hulls are usually built on bulkheads. To obtain better protection against corrosion they are generally of the open-angle-section type, thus differing from the closed-section type of airplane fuselages. The longitudinal structure consists of open angular parts and is seldom stiffened by closed sections. The covering consists of smooth sheet metal Corrugated metal can be used only for the sides and top. The strength of the bottom sheets should be from 0.5 to 0.7 kg/cm² (7.1 to 10 lb./sq.in.). Easy access to all parts is strictly required.

Metal hulls involve a considerably higher expense. The advantages and disadvantages of wood and metal are best evaluated in Italy, where the Savoia and Dornier flying boats are made. (The directors and personnel of the Dornier metal aircraft factory at Pisa are all Italian.) Italy does not have large resources. Consequently, she does not want to pay a much higher price for only a slight increase of useful load and she has not, thus far, bought a single Dornier Wal. The fact that metal is more weatherproof becomes negligible where there is a good ground organization. Conditions were different for Spain in the Moroccan war.

Strength calculations should be governed by the following considerations: The bottom often receives heavy local impacts, which are transmitted by the covering to the bulkheads and the longitudinal structural members and hence to the engine and wing struts. On one side, the force is distributed over a large area, whereas on the other side, it is concentrated at a few points. On rough water, it frequently occurs that bow and stern are supported by two different waves. The central part is clear of the water and subject to bending stresses. Thereby considerable stresses are developed in the material of large hulls.

Referring to the aircraft illustrated in Fig. 68, it should be stated that there is no fundamental superiority of one special type over any other. Dornier claims that the actual superiority of his Wal lies in some of its distinctive features. This is an error. The superiority is due to the fact that the thorough development of all structural parts extended over a sufficiently long period of time (during the period of the limitation of aircraft building). Most types in Fig. 68 can be brought to the same degree of perfection if enough time and work are spent on them.

Although we Germans must realize that we are far behind other countries in the construction of float seaplanes, we should comfort ourselves with our superiority in the construction of flying boats and with the hope of producing better float seaplanes.

Discussion

<u>Dr. Madelung</u>: Mr. Herrmann suggests that, in addition to his model tests on float buoyancy and resistance in motion, similar tests on their stability at rest be conducted. Such model tests have already been instituted by the D.V.L. ("Deutsche Versuchsanstalt fur Luftfahrt"). Light and strong hollow models have been built by a simple method. Hull or float models are placed in a tank and loaded with weights and moments, whereupon the list is measured.

Model tests are not required for ordinary symmetrical cases. But as soon as oblique positions of immersion, larger listing, complicated float shapes or even leakages must be taken into consideration, the application of graphical shipbuilding methods becomes lengthy and intricate. Then there arises a demand for an experimental method. It is expected that these tests and their application will be simple and comprehensive.

Mr. Herrmann has given careful consideration both to flying boats and float seaplanes. I find no mention of the single-float seaplane, which is of standard construction mounted on a central float. Strange as it may seam, this seaplane type is neglected in Germany. I think there is a certain prejudice against it, because its advantages are not known. Still it was recommended to me by Commander Richardson, U.S.N., as being particularly seaworthy. It is used in America as a training airplane and as a shipboard seaplane in the Navy. I was told this is due to the fact that single-float seaplanes are the only aircraft which can be catapulted. This affirmation is not correct. Twin-float seaplanes can be catapulted in the same way.

The single-float type is particularly advantageous, owing to its great strength. It does away with lateral impacts and unequal load conditions which are difficult to absorb. The front portion of the float, which is subjected to great stresses on striking a wave crest, can be braced from the engine mounting. Twin-float seaplanes are used in the American Navy only when strictly required, as for bombing and torpedo-carrying purposes, when a free space beneath the fuselage is essential; for high-wing seaplanes, where wing-tip floats would require too long struts, and for very small seaplanes (submarine seaplanes).

Mr. Herrmann claims that a damaged wing-tip float entails the breakdown of the seaplane. I cannot agree with him. Even if a wing-tip float should eventually come off, a reserve float chamber could be arranged above it in the wing, for example. Of course this method can only be applied to low-wing seaplanes, which are extensively used in Germany.

H. B. Helmbold: I should like to make some comments on the application of the results of float-model tests to full-sized floats. The flow stresses created are subject to the influence of gravity and tenacity. Hence, according to the mechanical laws of similarity, no absolute mechanical similarity can be obtained with a model test. Anyway, the influence of gravity is such that the curves obtained by plotting the resistance (or drag) coefficient $\frac{W}{qV^{2/3}}$ of the floats against Froude's number $\frac{v}{\sqrt{gL}}$ do not lie very far apart. The remaining divergences are then due to differences in the Reynolds Numbers $\frac{vL}{\nu}$. It appears from plate-friction measurements that the model has a comparatively higher skin friction than the actual seaplane, but it seems as though the real observed increase of relative friction is too high to be caused directly by friction. Moreover, the value of the critical Froude number changes when applied to models. This attitude is explained by the nose-heavy trim moment, which is probably due to the increase of the model skin friction and to the increase of the thrust component acting high above the float and required to maintain the forces in equilibrium. This assumption is confirmed by the fact that changes of the resistance curve of the actual seaplane can be produced by exerting a nose-heavy trim moment (i.e., shifting the c.g. of the actual seaplane to the front), these changes corresponding to those arising from the reduction of full-size data to model data.

Captain Boykow (retired naval captain): The lecturer claims that a single-float seaplane or a flying boat breaks down if one of their wing-tip floats comes off. This may be a little exaggerated. The danger resulting from a float coming off must be somewhat similar to that encountered by a train running past the stop signal. Accidents may occur in some cases, but stop signals are often run past without causing trouble. I consider there is about one collision every 50 times a train runs past a stop signal. The same proportion can probably be applied to seaplanes losing a wing-tip float. I know of several cases when wing-tip floats were actually crushed in at the take-off without preventing the seaplane from alighting in excellent condition after a completed flight. I even witnessed a case when a wing-tip float was crushed in while alighting at night. Next morning, the seaplane took off faultlessly with a single float and alighted after a completed flight. Therefore, I do not really think that an accident is unavoidable when a wing-tip float comes off.

F. Z. Diemer: The lecturer has not referred to the importance of the planing angle (angle at which the hull is set to the surface of the water) during tank tests. This angle can exert a considerable influence on the resistance. To get a complete idea of resistance conditions, the resistance curves should be measured over a speed range for different loads and different positions of trim, a much higher number of observations being thus required. A set of resistance curves is then obtained, from which the most favorable take-off conditions for a given hull shape can be determined, provided the change of aerodynamical lift resulting from a different position of trim is taken into consideration. I do not agree with the lecturer as to the effect of the lift on the take-off, which he considers to be negligible. When speaking of hull shapes, the lecturer emphasized the advantages resulting, according to tank tests, from a sharp V-bottom. I think no general conclusions should be drawn from test results, as they are liable to be premature. In this connection, attention is drawn to the following points which, along with the V-bottom, may affect the seaworthiness and take-off ability.

The length of the hull portion lying in front of the step, compared with the position of the c.g. and with the radius of gyration of the whole seaplane around the transverse axis, should be considered for the determination of the attitude of the seaplane on rough water. If a point of the hull bottom at a distance x, from the c.g. receives a vertical acceleration b, from a head wave, the required force is

$$P = G' \left(1 - \frac{x^2}{i^2} + G \frac{b}{g}\right) \tag{1}$$

where G = total weight,

G' = the part of the total weight not supported by the wings,

g = acceleration due to gravity,

i = radius of gyration.

As soon as P becomes $< G'$ there is

$$P = G \frac{i^2}{x^2} \frac{b}{g} . \tag{2}$$

For the force acting below the c.g., formula (1) changes to

$$P = G' + G \frac{b}{g}.$$

This curve is plotted in Fig. 71. Its turning point lies at $P = G'$. For $b = g$ and $G' = G$, the abscissa of the turning point becomes $= i$.

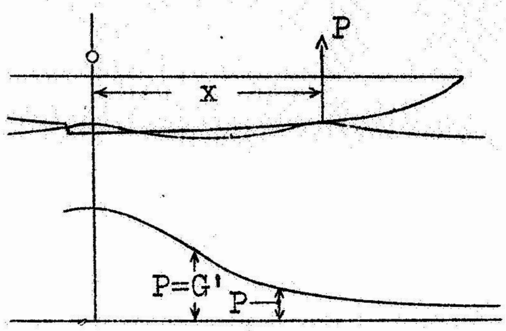


Fig.71

The highest local stress exerted by a wave is reduced with increasing distance of the c.g. from the point of the wave impact and with decreasing radius of gyration.

It is therefore quite possible that no higher stresses are imposed on a hull with a long front portion than on a short V-bottom hull. Shorter hull and higher moment of inertia of the seaplane call for sharper lines of the front part to withstand the impacts of the waves.

The development of the V-bottom over the whole length of the hull has a considerable influence on the formation of spray. If the cross members are sharp-edged at the bow and gradually flattened out toward the rear, no spray will be thrown up from under the chine at high speed and the waves will be steadily deflected toward the surface of the water. These facts were confirmed by successful tests with motor boats of the so-called "wave-binding type." Suitable application of this principle to flying-boat hulls and seaplane floats results in the creation of hulls or floats which, notwithstanding a comparatively flat bottom near the main step, will run smooth and dry through the seaway.

From the above remarks, it will be understood that in each case various additional points must be taken into consideration for the determination of hull shapes, these points having a direct bearing on the required characteristics of the lines. Therefore, one should be very cautious in applying acquired experience to new designs.

In view of the success obtained with English sharp V-bottom flying boats it should not be forgotten that, so far as I know, their wing and power loading is much lower.

A comparison of the "factor" (power loading $\times \sqrt{\text{wing loading}}$) affords a good basis for the calculation of take-off characteristics which are not substantially affected by the aerodynamical properties of the seaplane. This factor lies between 65 and 70 for good German flying boats. I should like to know this factor for English flying boats and I am sure that flatter German seaplanes would easily stand a comparison.

Finally, I want to refer to the question of Dornier Wal flying boats in Italy. The technical direction of the Pisa factory working under license from Dornier-Metal-Construction is in German hands. Purely political reasons prevented Italy for a certain time from ordering Dornier Wal flying boats. At the present time, a certain number of these seaplanes are doing service in the Italian air force and they prove quite as satisfactory as they have done in other countries. Besides, their price does not very much exceed that of Italian wood flying boats of the same size.

Professor Von Karman states that a graphical method of calculation based on hydrodynamical tests has been developed by Mr. Verduzio for the determination of seaplane take-off curves. This method is outlined in the "Lectures on Hydrodynamics and Aerodynamics," Innsbruck, 1922.

Referring to Dr. Madelung's remark, Professor Von Karman pointed out that very satisfactory test results were obtained at the Aachen Technical High School, with an adjustable single-wheel landing-gear model.

Dr. Roland Eisenlohr: In reply to Dr. Madelung's arguments, I beg to state that we already had a single-float seaplane in Germany in 1911, namely, the 135 HP. Kober-Friedrichshafen biplane. At that time this biplane competed with an Albatros twin-float biplane piloted by Hirth in the 50 kg (110.2 lb.) circuit which was won by Hirth with only a slight margin of 1 or 2 seconds. This good performance of the large biplane against the small and rapid monoplane was no doubt due to the rapid take-off and alighting as well as to the low air resistance of the central float.

A decision in favor of the single or the twin-float seaplane depends entirely on the design of the seaplane. A float gear offers considerable advantages, owing to the fact that it can be braced from the wings, which cannot be done with a landing gear. Besides, it increases considerably the height of the framework. The framework height of a float biplane is actually that of a triplane, while a float monoplane has the height of a biplane (for example, the unbraced Brandenburg monoplane). When applied to cantilever wings, the lateral distance between the floats, which might be used for the framework and the height of the twin-float system, lose their importance. It appears to me that the Dornier flying boats followed a logical course of development, the central hull independent of the wings being developed simultaneously with the cantilever wing. Under these conditions, it would be wrong to let a braced biplane miss the advantages of the twin-float system and a cantilever monoplane assume its disadvantages.

With reference to the superiority of the Dornier Wal hull, it seems to me that it lies chiefly in the shape of the hull aft of the step. I call particular attention to the question of the long hull or short hull with raised after-body, which was not mentioned by Mr. Herrmann. The short-hull shape offers, without doubt, considerable advantages, and it was Dornier's starting point. It is also extensively used in England and America.

H. Herrmann (Conclusion): I beg to thank Messrs. Madelung, Boykow and Eisenlohr for the completion and rectification of my lecture. In reply to Mr. Diemer's arguments, I should say that a normal tank test is based on the determination of the best position of the c.g. I assumed the general theory of tank tests to be known. The influence of the position of the c.g. with reference to the step is evidenced by the text accompanying Figs. 17-25. The forthcoming Hamburg article will contain further information.

Mr. Diemer's calculation proves with particular clearness that the step receives the highest impacts and should therefore be of V-bottom shape. I have repeatedly emphasized the necessity of a long bow.

The "factor" is often used in Germany for the determination of airplane characteristics. This "factor" affords but little information. Performances, maneuverability, attendance, number of current repairs, price and many other important data are never to be found in books or in publications issued by airplane firms.

Translation by W. L. Koporinde, Paris Office,
National Advisory Committee
for Aeronautics.

Length of model 1.14 m Displacement 5440 kg

Model No. 354 F3

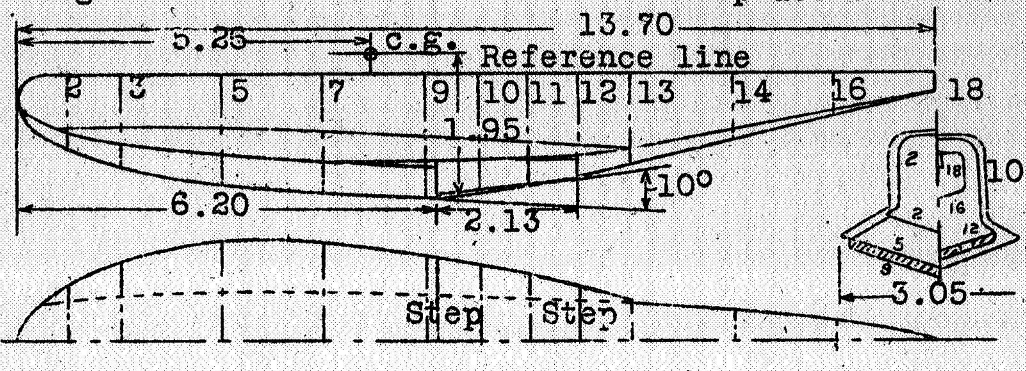


Fig.33 Lines of the F3. Design of the English Flexstone research laboratory.

Length of model 1.14 m Displacement 5440 kg

Model No. 353A P5/II

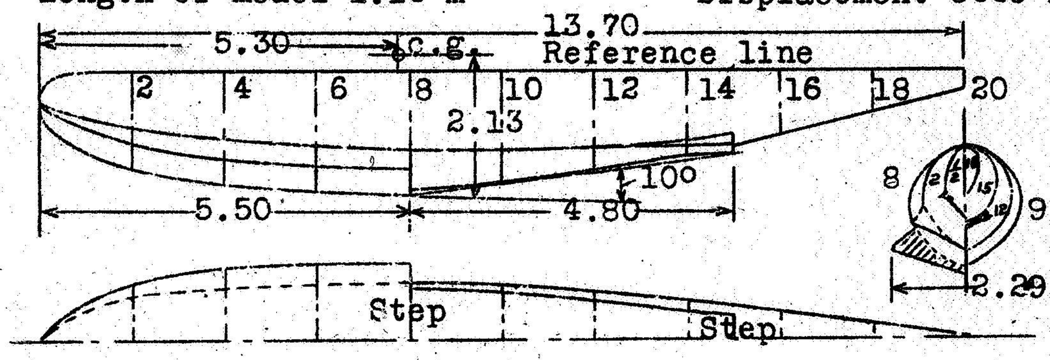


Fig.34 Lines of the P5. Design of the hull by Linton Hope, of the craft by Manning, yard of the English Electric Company. Also see Fig.65.

Length of model 1.14 m Displacement 5440 kg

Model No. 353B

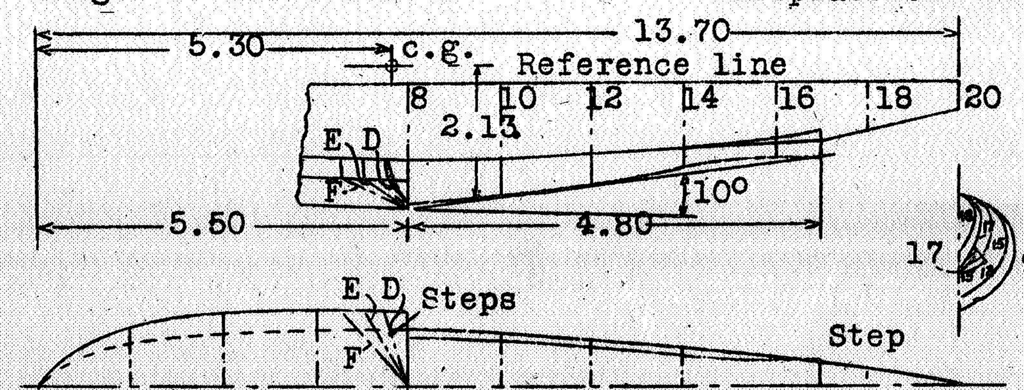


Fig.35 Attempted changes of the step. (No improvement)

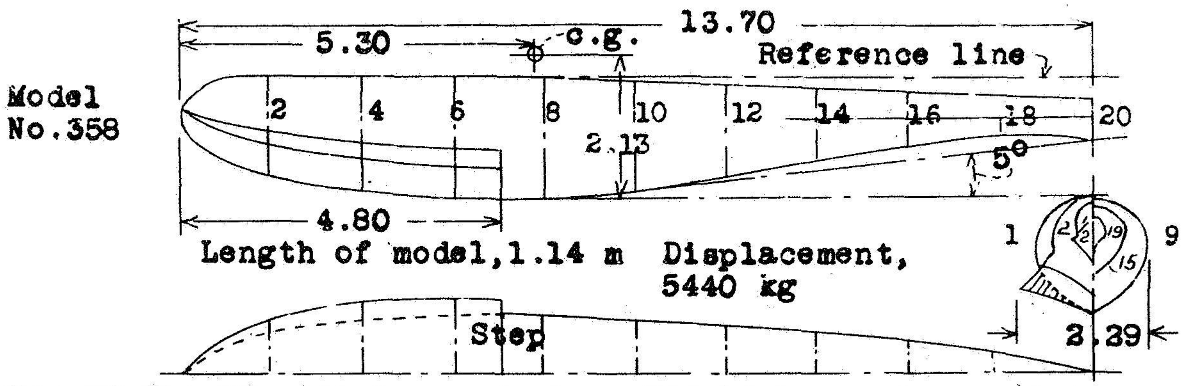


Fig.36 The P5 with lowered step. Had higher water resistance.

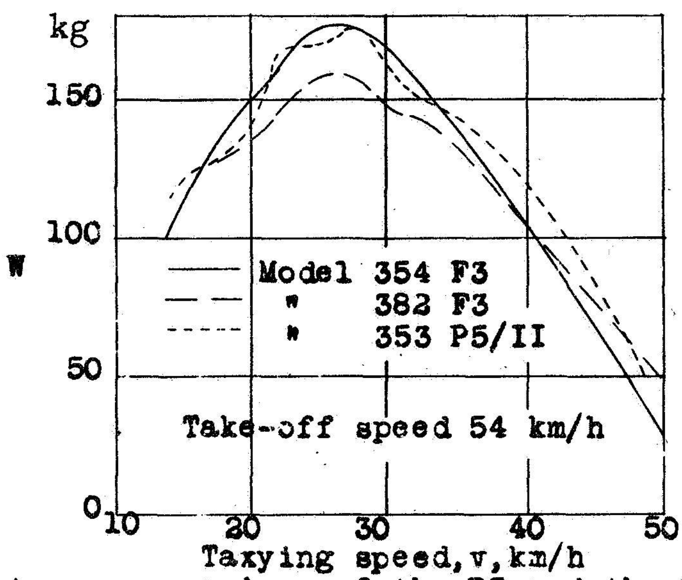


Fig.37 Resistance comparison of the P5 and the F3.

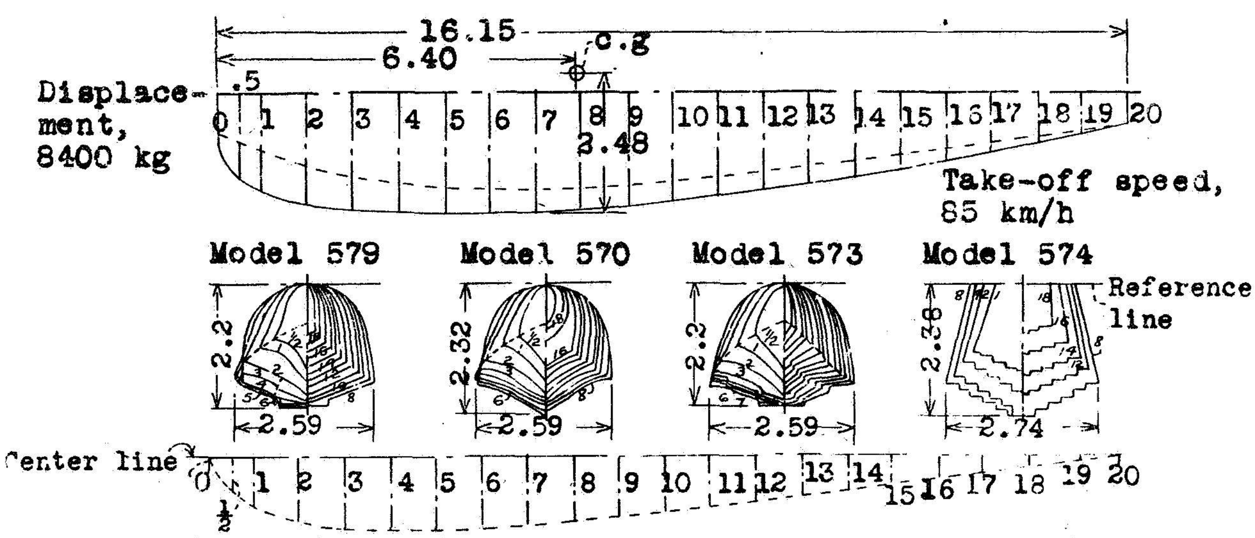


Fig.38 Lines of 4 hulls with longitudinal step, but without transverse step.

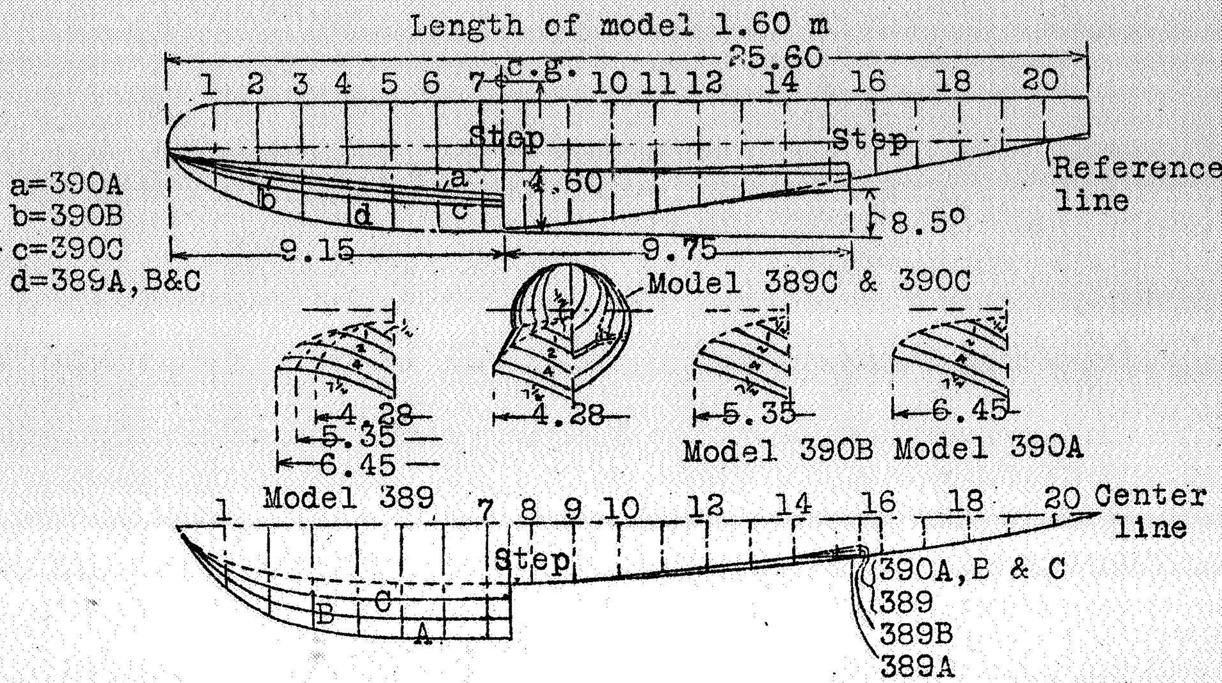


Fig.40 Lines showing different methods of widening a P5.

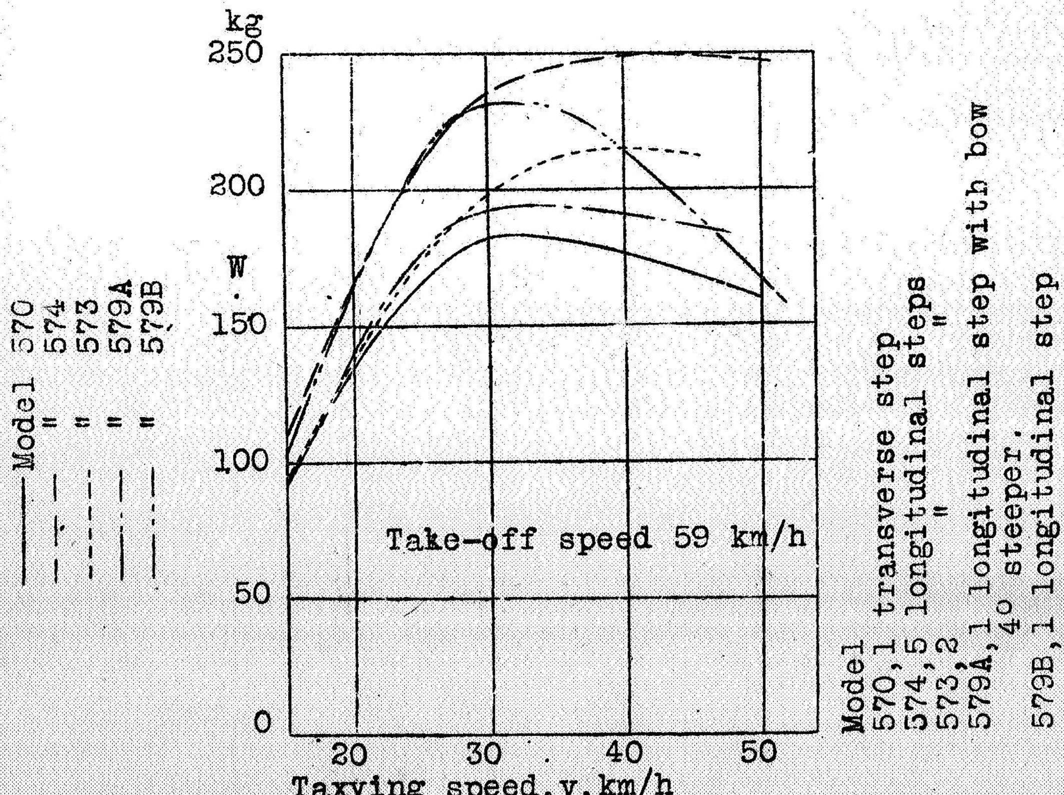


Fig.39 Water resistance of hulls with longitudinal steps compared with transverse steps, which proved to be superior.

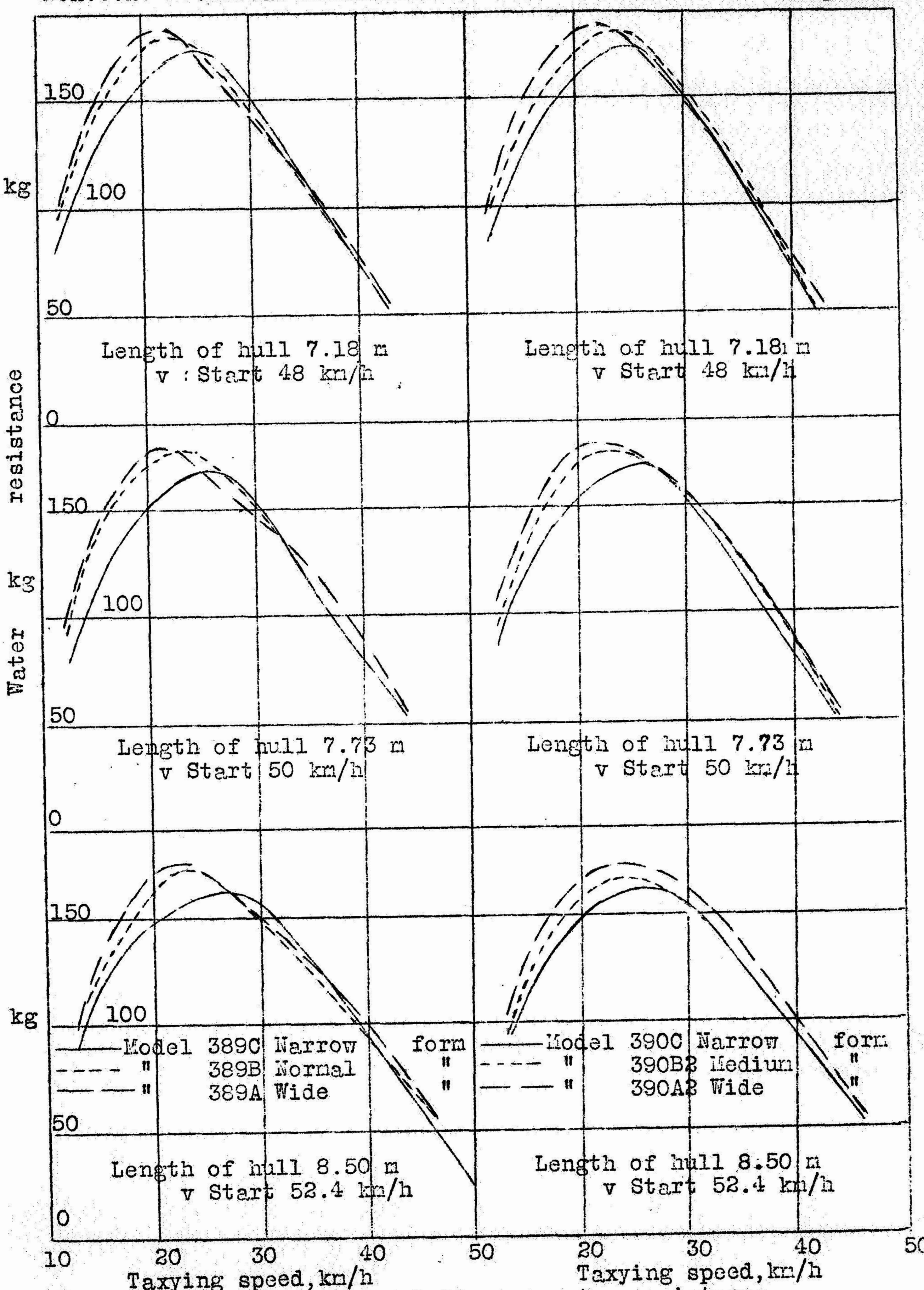
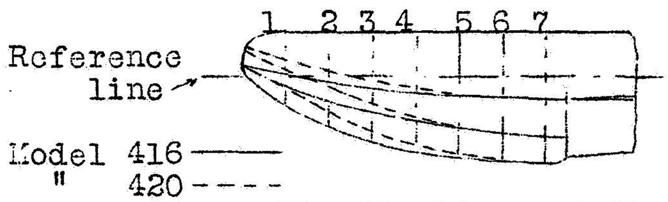
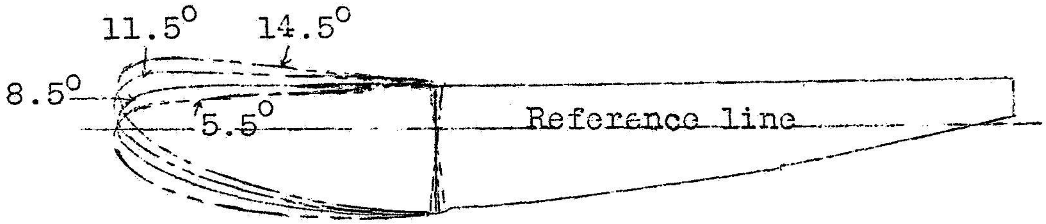


Fig.41 Effect of widening hull upon water resistance.



From rib 6 to stern same as model 389C
From rib 6 to bow, ribs 389C (except rib 1) raised to new keel line.

Fig.42 Lines of the P5 with different positions of the front portion.



Model No.389C with various front portions. Normal position 8.5°

Fig.43 New lines derived from the tests with the models of Fig.42.

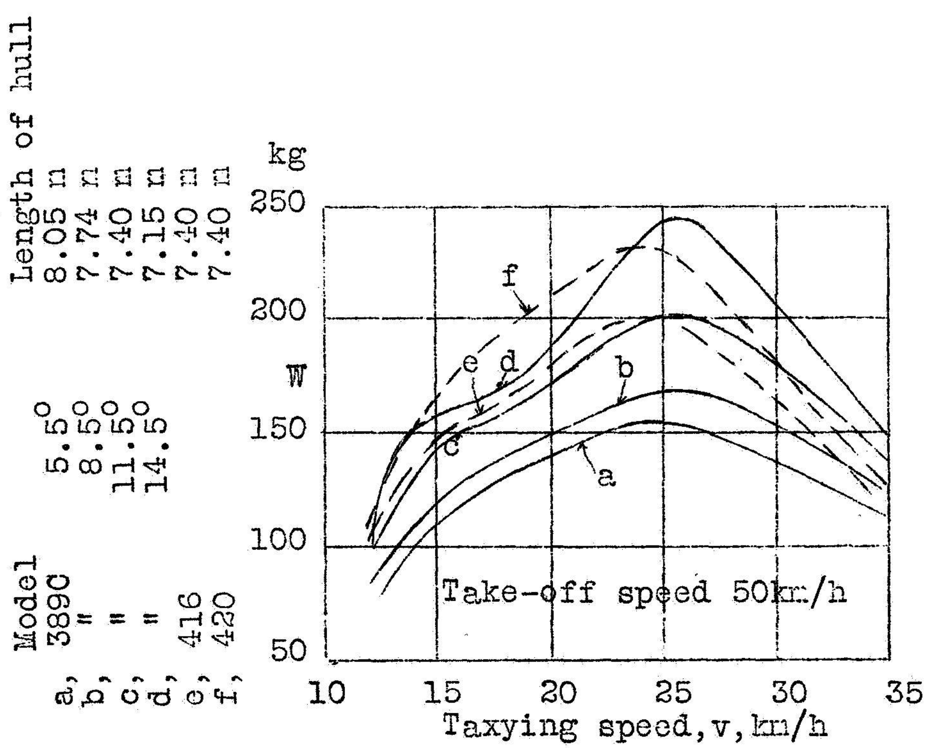


Fig.44 Water resistance of the models of figures 42 and 43 when the formation of spray is strictly identical.

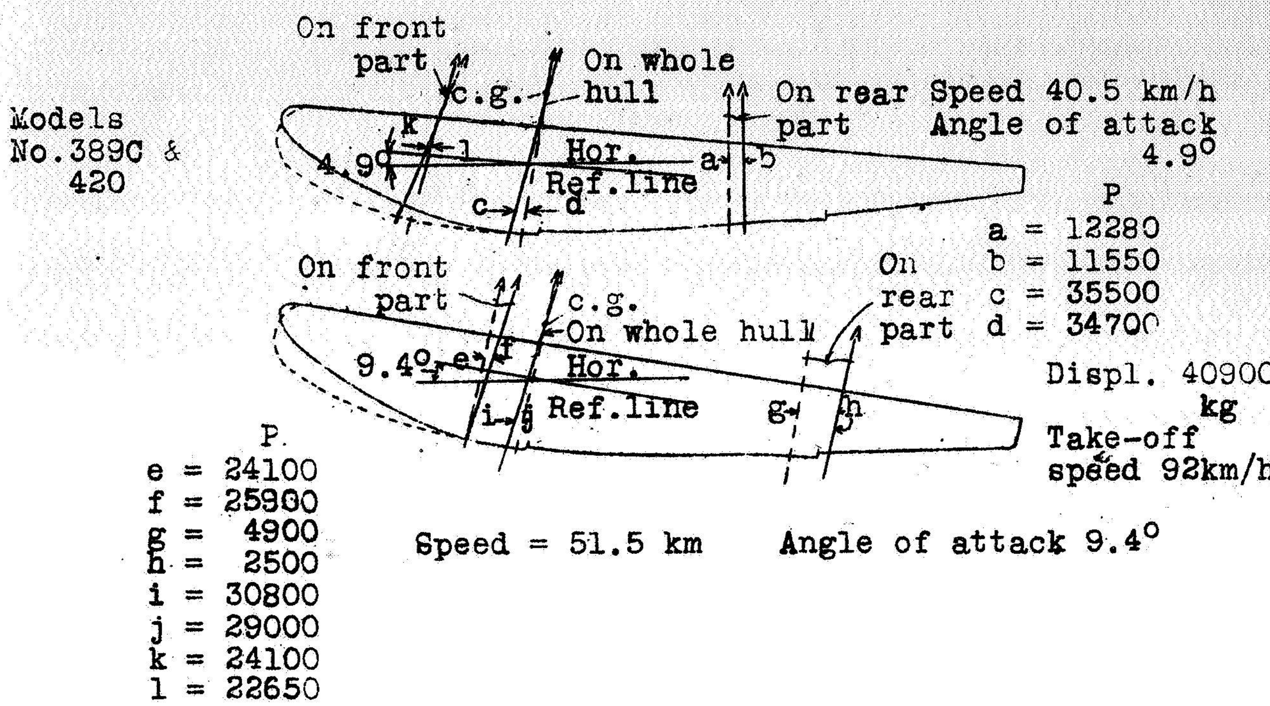


Fig.45 Resultant forces acting on a hull.

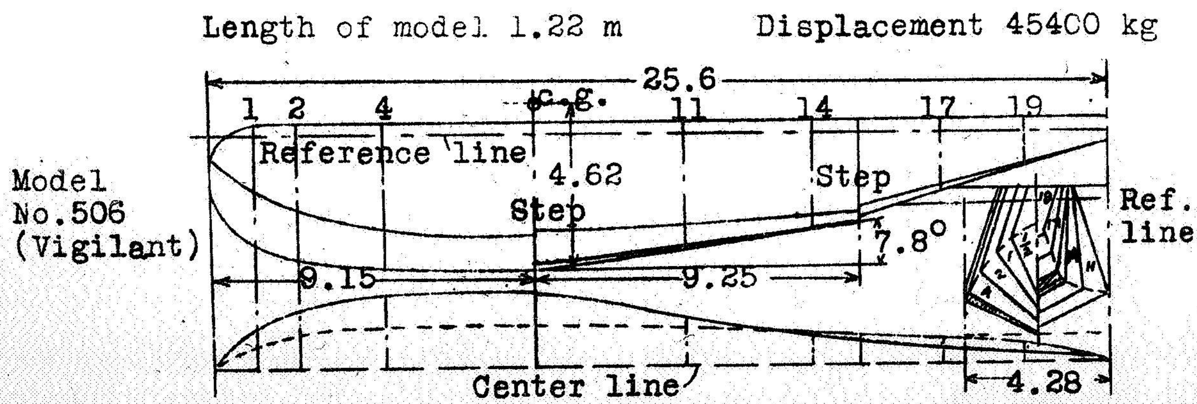


Fig.46 Lines of the Vickers Vigilant. All contours straight.

Model No.389H

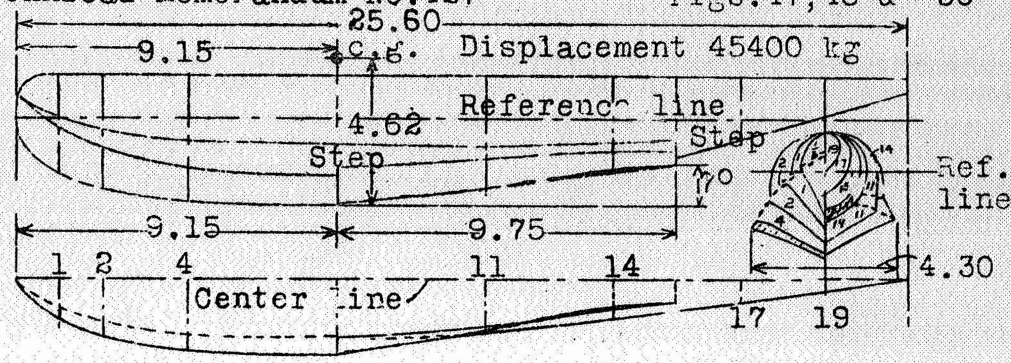


Fig.47 Lines of a comparative model of Fig.46, with curved contours.

Length of model 1.60 m Displacement 45400 kg

Model No.389D

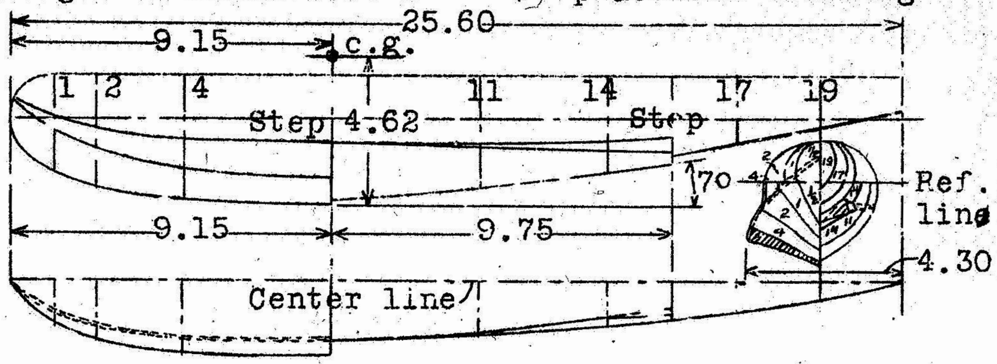


Fig.48 Lines of a comparative model of Fig.46, with curved contours.

Length of model 1.04 m

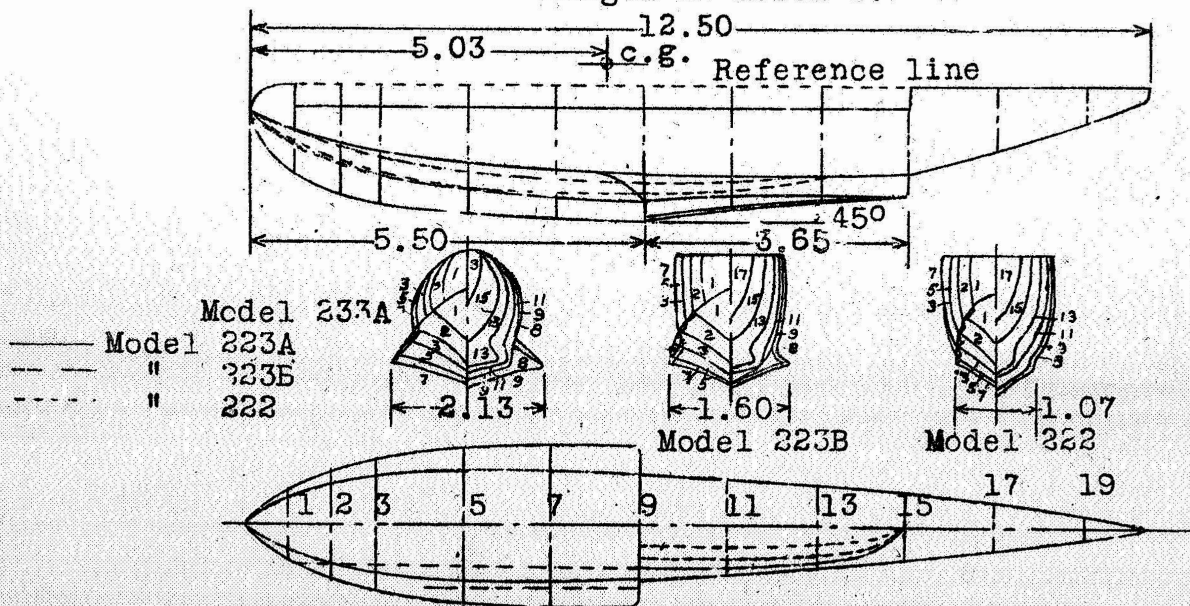


Fig.50 Three different widths of the P5.

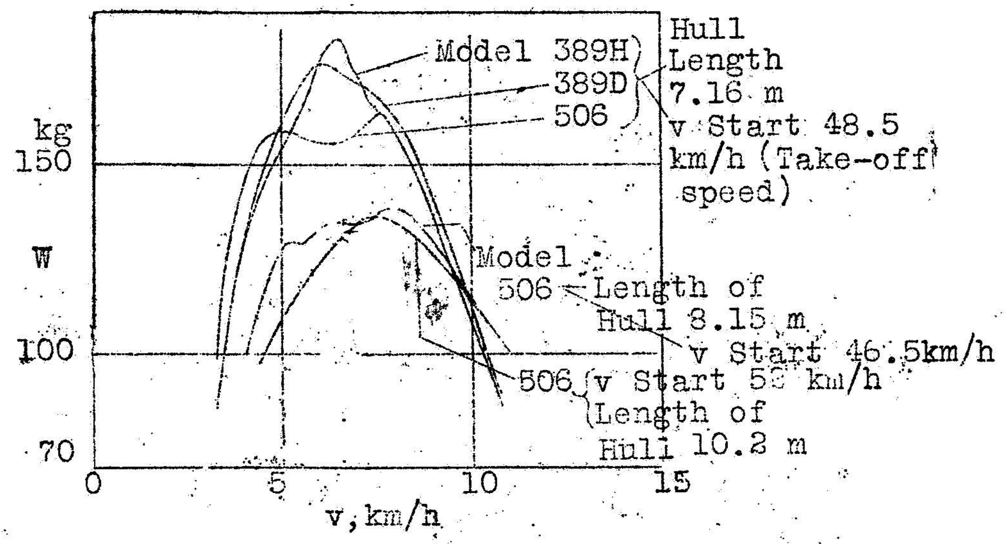


Fig.49 Water resistance of hulls from Figs.46-48.

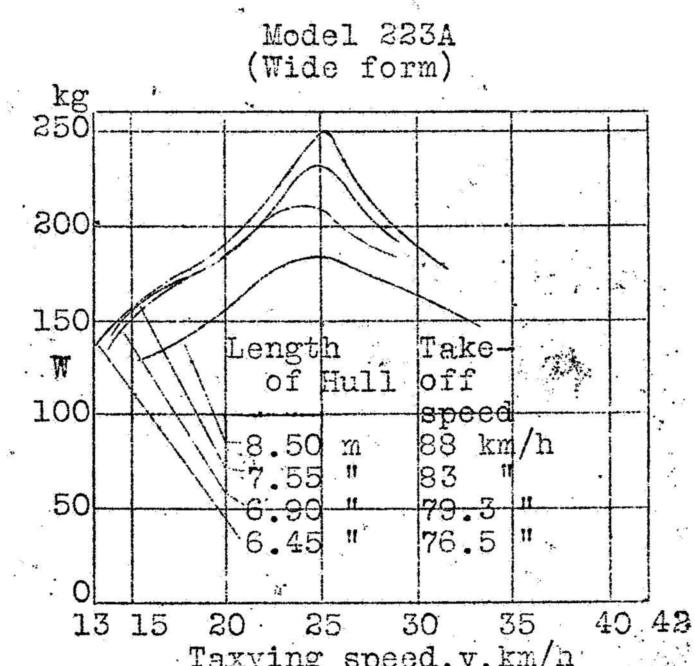


Fig.51 Water resistance of the normal P5.

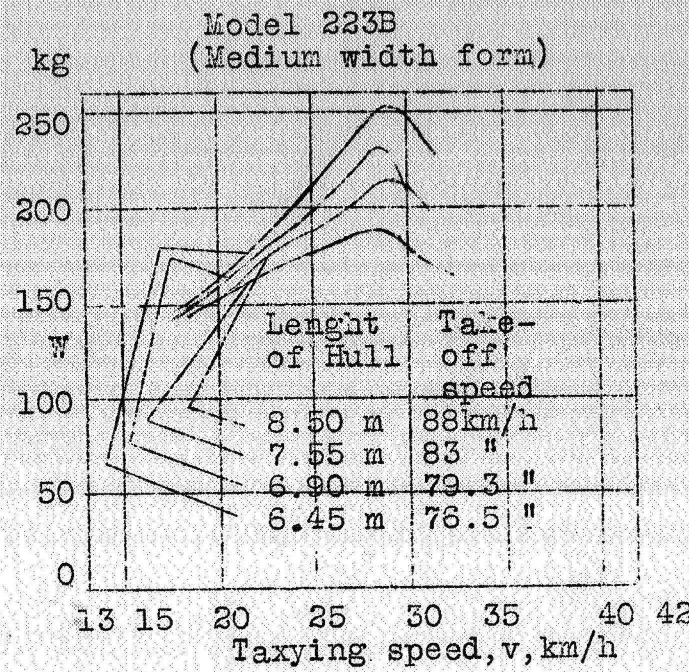


Fig.52 Water resistance of the P5 with slightly reduced width.

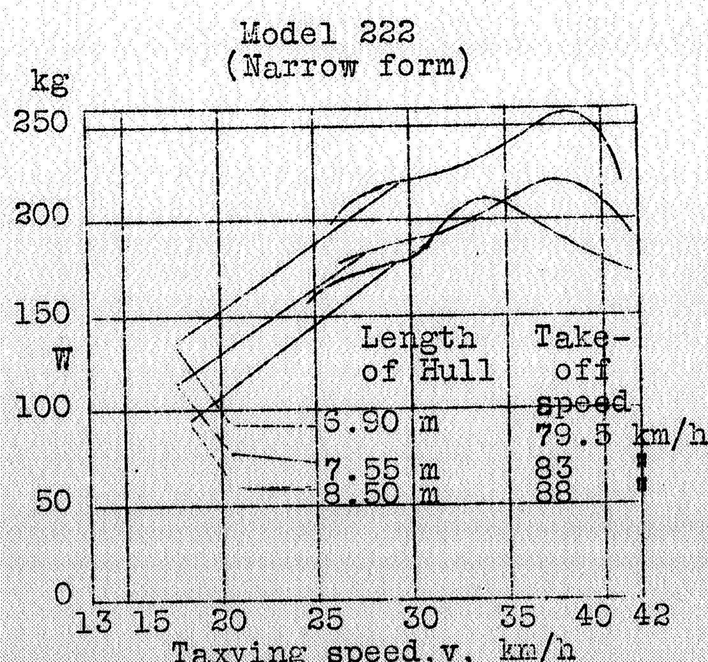


Fig.53 Water resistance of the P5 with greatly reduced width.

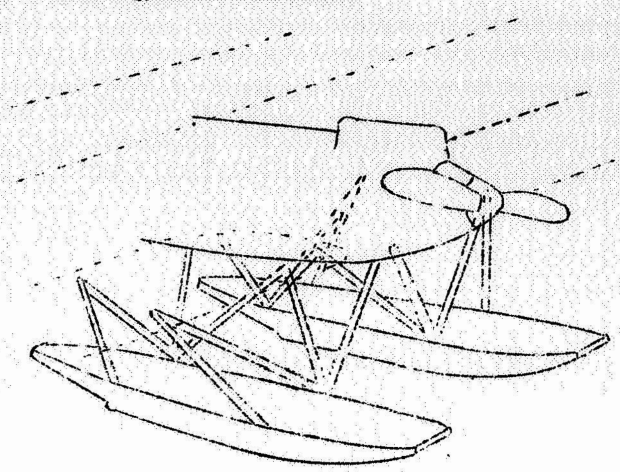


Fig.55 Landing gear of the Friedrichshafen F.49.B. Many struts.

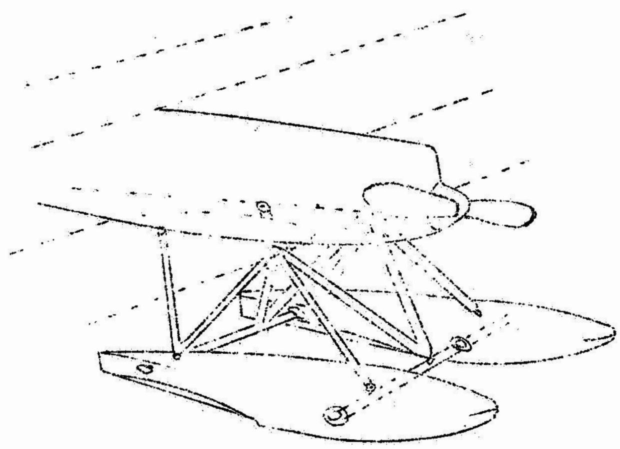


Fig.56 Landing gear of the Udet U.13. "Bayern". Few struts. Strong horizontal connecting tubes.

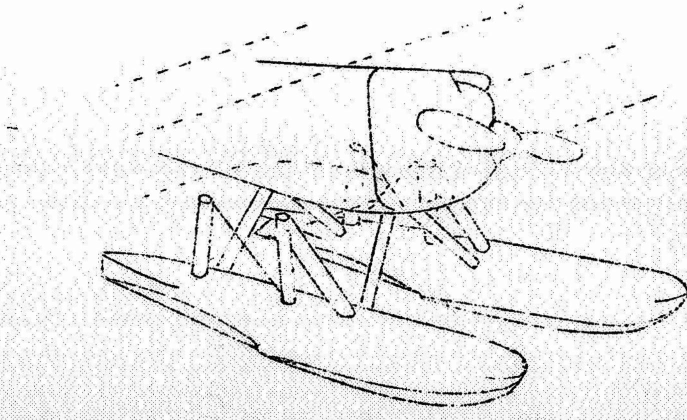


Fig.57 Landing gear of the Curtiss CS torpedo carrier.

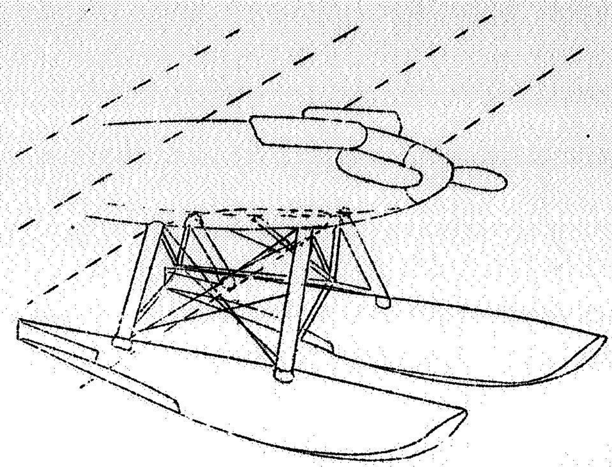


Fig.58 How the landing gear should not be designed.

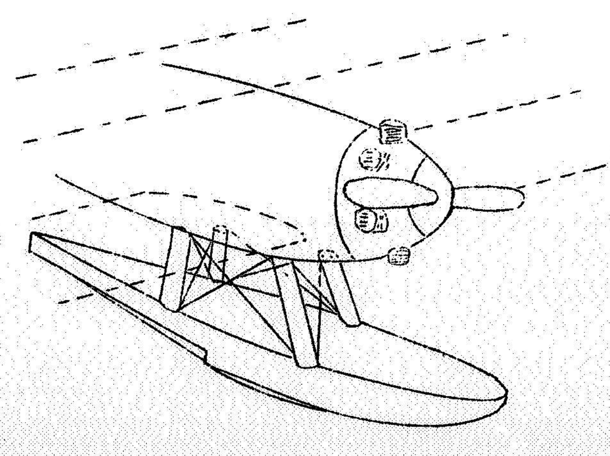


Fig.59 Single-float landing gear.

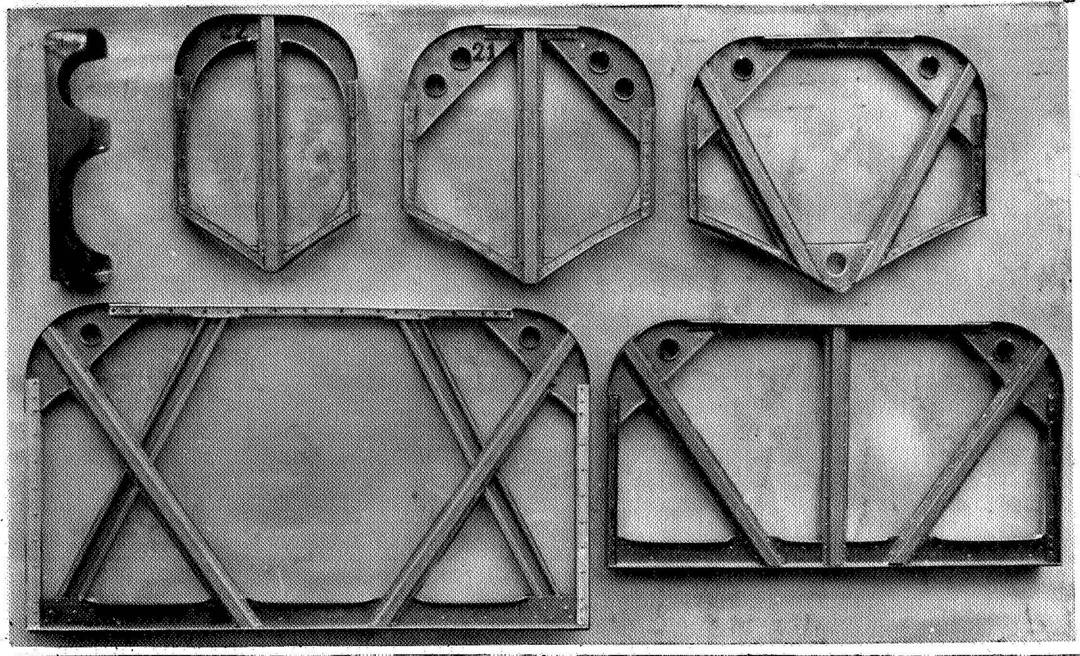


Fig. 60

Metal-float bulkheads. Udet airplane factory.

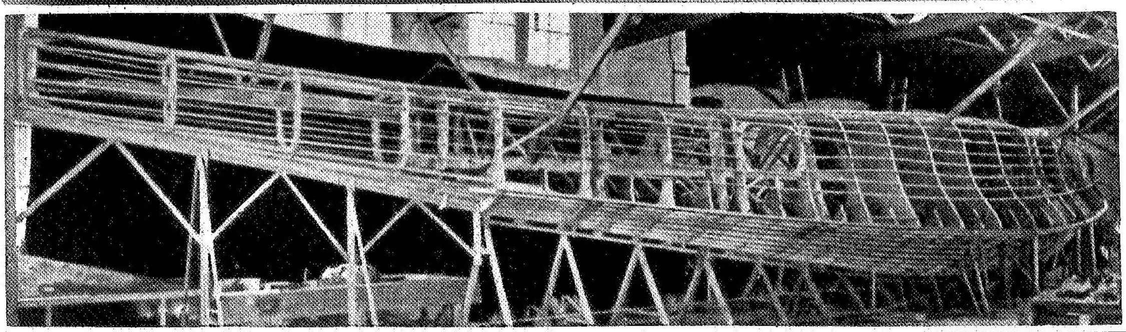


Fig. 61

Framework of the N.4. Atalanta. See Fig. 31

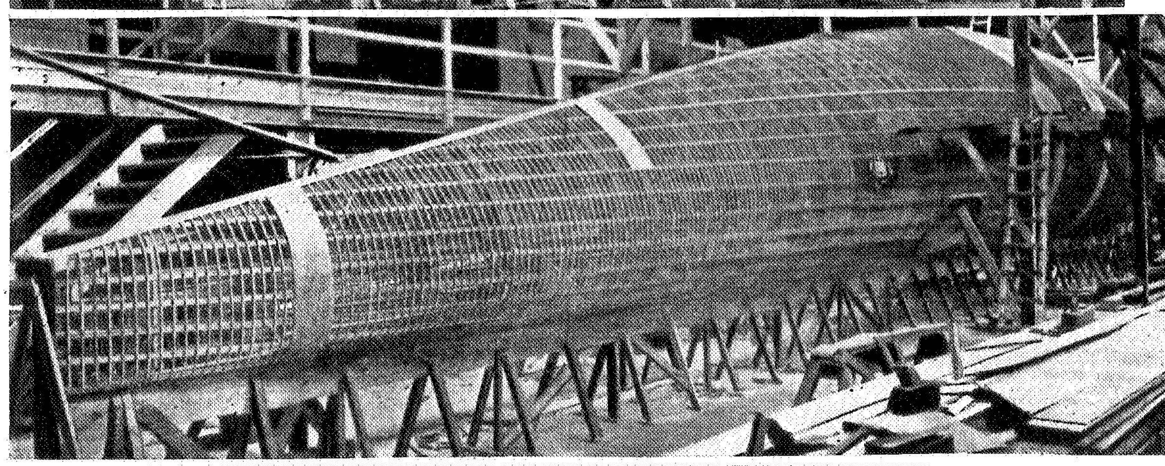


Fig. 62

Framework of the N.4 Titania See Figs,29 and 30

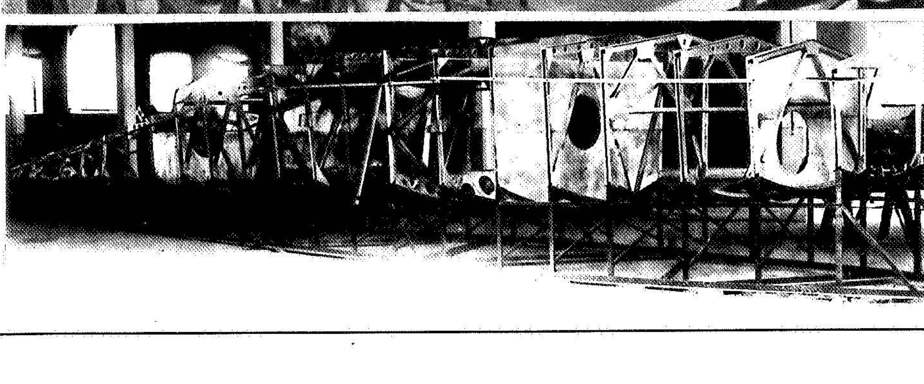


Fig. 63

Framework of the Dornier Wal.

7012-A.S.

Fig.66 The Dornier Wal.

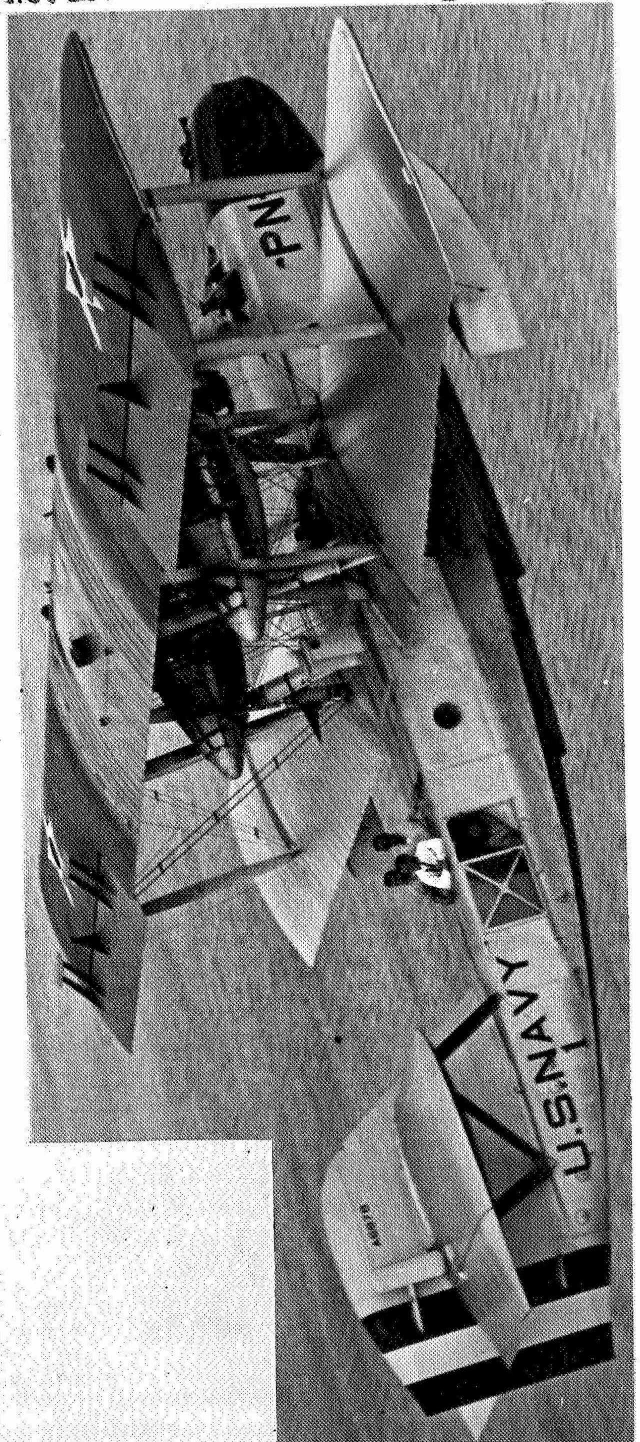


Fig.64 The American P.N.9 flying boat. Metal hull, wood wings.

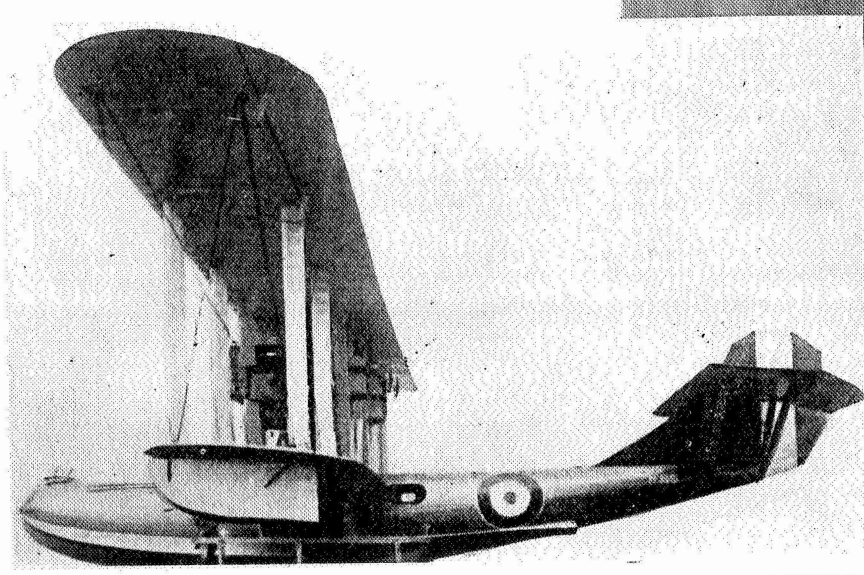


Fig.65 The P.5

7010-A.S.

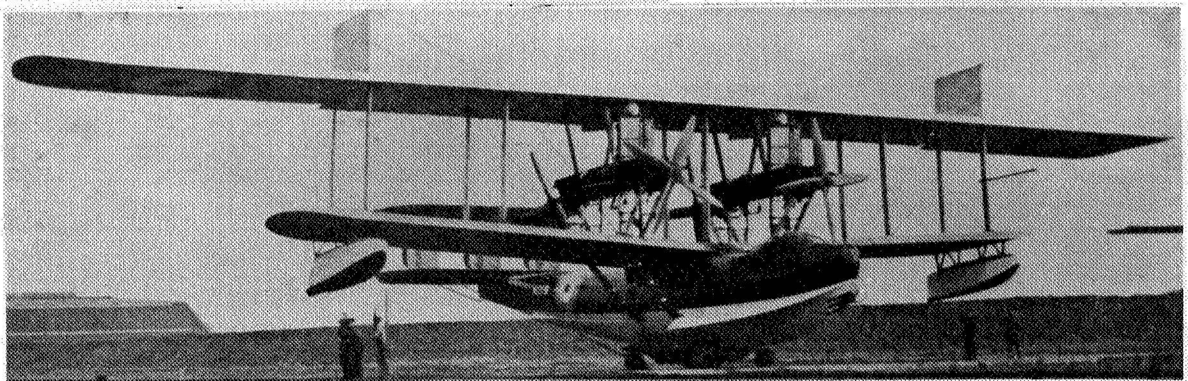


Fig.67 Fairey N.4 Atalanta, the world's largest flying boat.

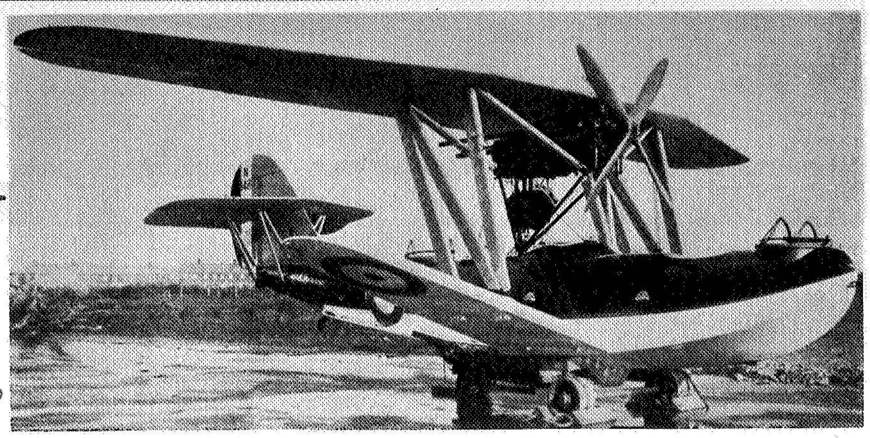


Fig.69 English experimental flying boat without wing-tip floats and with lower wing in the water. Built by the English Electric Co. Designer, O. Manning.

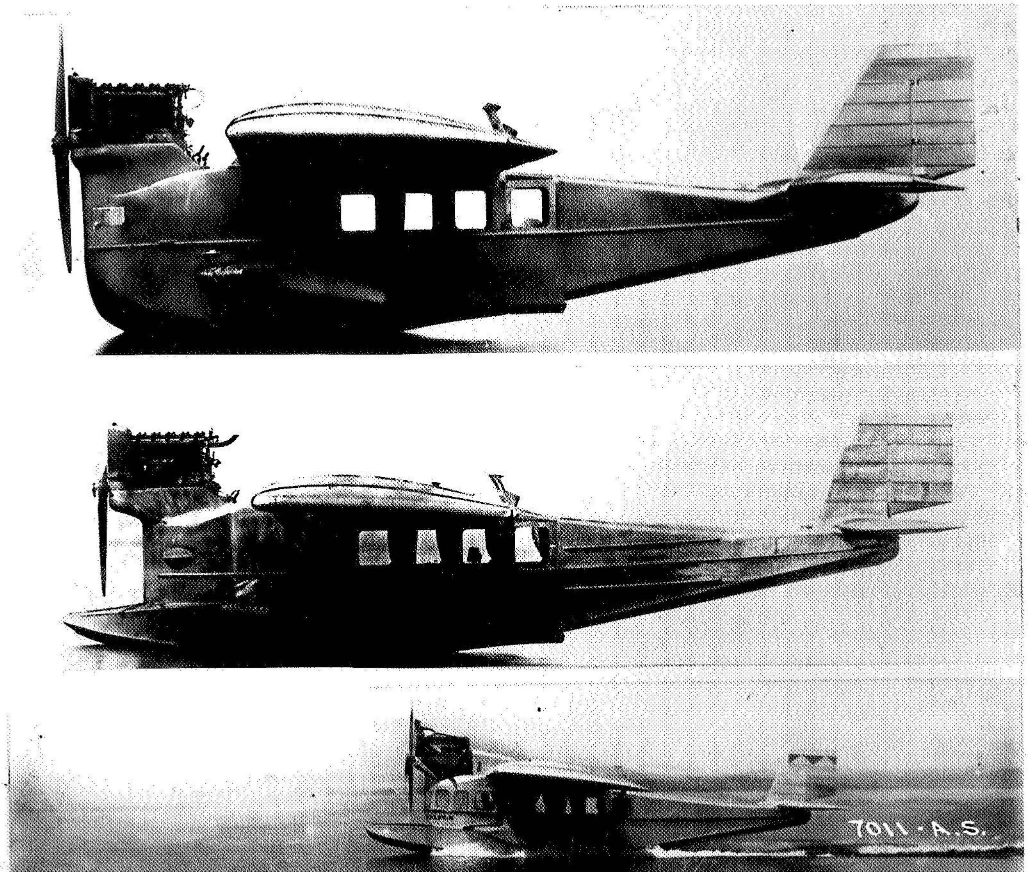


Fig.70 Three modifications of the Dornier "Delphin". The bow of type shown in top fig., was extended producing type shown in middle figure. That in bottom figure contains a 360 HP.Rolls-Royce eng., instead of the 230 HP. B.M.W.IV, with pilots seat under engine.

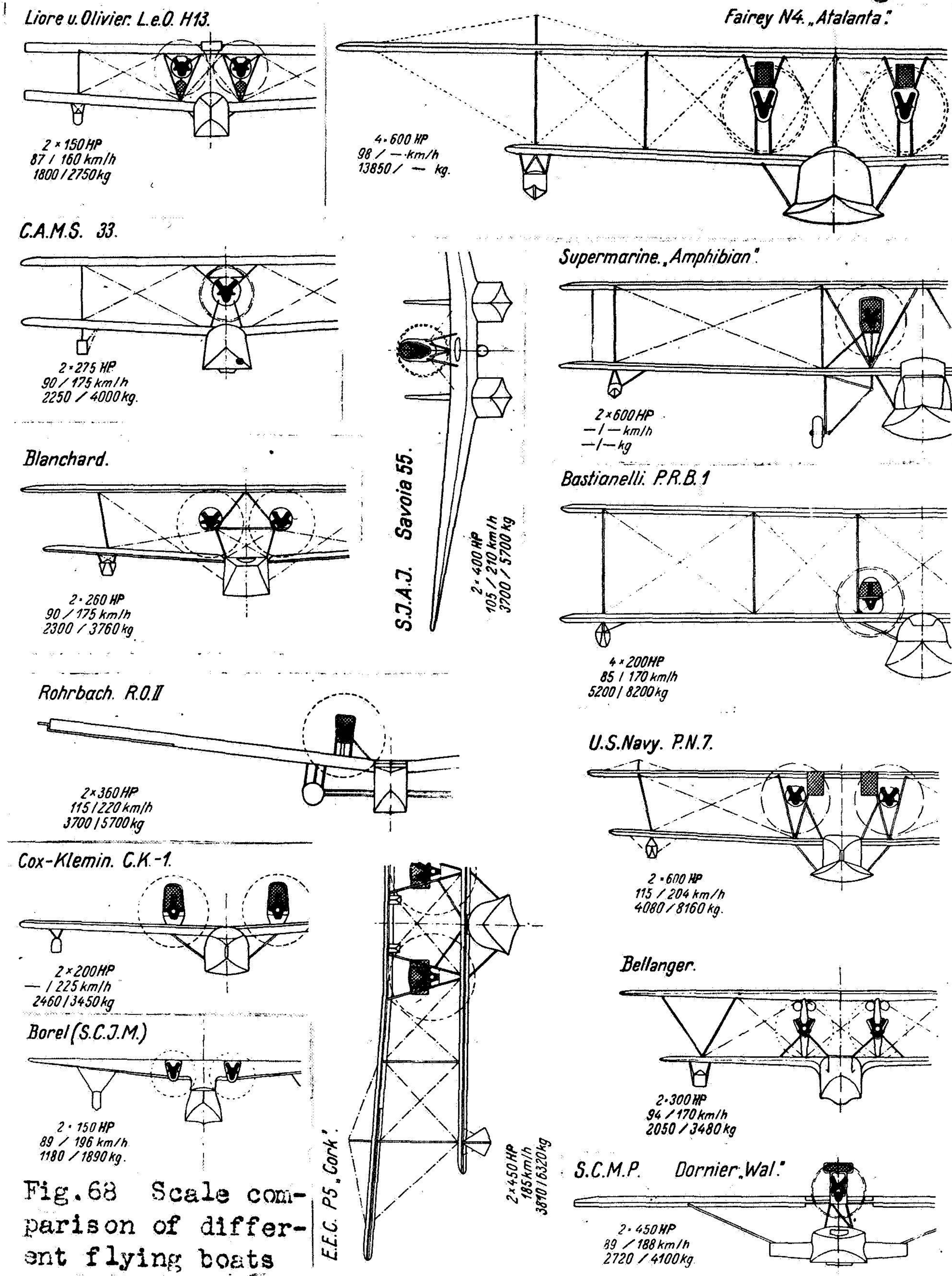


Fig. 68 Scale comparison of different flying boats